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# A Novel PROGRAMMABLE DISAGGREGATED EDGE NODE SUPPORTING HETEROGENEOUS 5G ACCESS TECHNOLOGIES

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## Abstract

We demonstrate a programmable disaggregated edge node in support of both metro and long-haul networks. This solution is successfully evaluated through Bristol's City Metro Network, over 100km and 200km optical fibre with a low power penalty.

## 1 Introduction

The emergence of new and diverse types of applications available to end users and vertical industries each requiring its own Key Performance Indicators (KPIs) have led to rapid progress in the development of 5G network architectures and technologies, including cell densification. In view of this, optical transport network solutions offering fronthaul, and backhaul services will play an important role in meeting these KPIs specifically in terms of the required delay, bandwidth, and synchronisation. The diversity of applications, their KPIs, as well as the diversity of 5G access network technologies that will share common transport network solutions require a flexible and programmable edge node architecture to offer the interface between the 5G access and transport network. This transport network can be envisioned to extend to both metro and core networks offering connectivity to distributed and centralised compute resources as required. To offer the required flexibility levels, this edge node has to be dynamically configurable and programmable via the network control plane to meet the needs of the different applications and access technologies.

time we present a disaggregated edge node that can be programmed on demand to support multiple front/back haul protocols such as CPRI/eCPRI and Ethernet. This node can also aggregate/dis-aggregate any input access traffic to/from a highly synchronous and bandwidth granular optical transport based on time slot switching in a programmable way. However, the same node can offer access to a highly programmable coherent variable bandwidth transponders suitable for spectrally elastic long-haul transmission.

## 2 Disaggregated Edge Node architecture

Fig.1 shows the proposed Disaggregated Edge Node architecture<sup>1,2</sup> comprising the Time Shared Optical Network (TSON) technology implementation using Field Programmable Gate Array (FPGA) optoelectronic platform, Voyager, and Wavelength Selective Switches (WSS). This highly programmable Software-defined networking (SDN) enabled architecture can aggregate/disaggregate any access traffic combination (i.e. Ethernet, WiFi, LiFi, eCPRI, and etc) to/from a transport network that can support both Metro- and Long-haul networks on demand based on the operator or service provider requirements.

### 2.1 Time Shared Optical Network (TSON)

TSON technology<sup>1,2</sup> has been proposed as a dynamic optical transport network solution to provide high bandwidth and low-latency connectivity in support of the 5G technology requirements. TSON is an active Wavelength Division Multiplexing (WDM) solution which provides variable sub-wavelength switching granularity and the ability to dynamically allocate optical bandwidth elastically<sup>1,2</sup> with a unique time-sharing mechanism. The time-sharing mechanism offers dynamic connectivity with different granularity of bandwidth to achieve the required Quality of Service (QoS). This technology is the first multiple protocol programmable

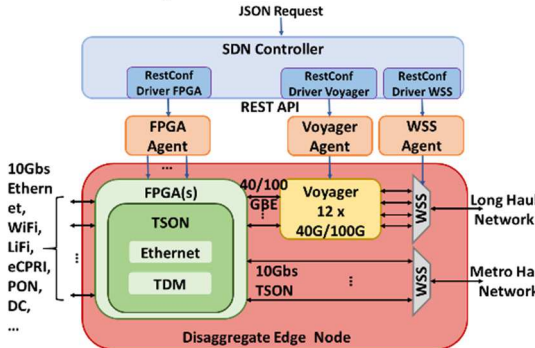


Fig. 1 Disaggregated edge node architecture

In this paper, we report on outcomes of the EU 5G Public Private Partnership (5GPPP), Metro-Haul<sup>1</sup> and 5G-PICTURE<sup>2</sup> projects focusing on a highly flexible and programmable solution to address the edge node of 5G networks. For the first

interface that meets 5G KPIs<sup>3</sup>. Fig. 2 illustrates the TSON data plane architecture in support of the disaggregated edge node. This architecture is fully programmable using SDN. The functions for the operation of TSON domains has been implemented in internal modules, within the SDN controller, that collaborate for the on-demand provisioning of connectivity between TSON nodes. The ingress TSON edge nodes are responsible for parsing, aggregation, and mapping of any input traffic combination with different bandwidth (in this implementation less than 10Gbps) into either 10Gbps TSON output with different granularity or converged 40Gbps Ethernet output, while the egress edge nodes have the reverse functionality.

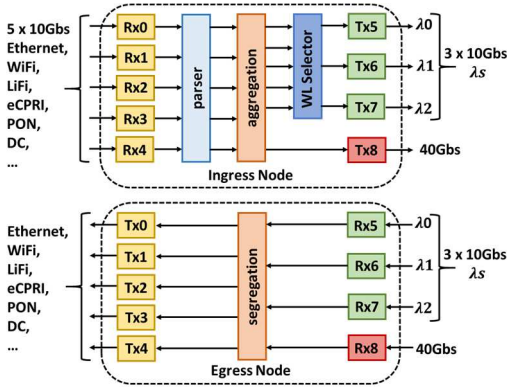


Fig. 2 TSON architecture for disaggregated edge node

### 2.2 Voyager

The voyager is a Broadcom Tomahawk-based switch with added Dense Wavelength Division Multiplexing (DWDM) ports called Voyager acting as a disaggregated optical transponder<sup>4</sup>. It hosts multiple Bandwidth Variable Transponders (BVT) that are capable of dynamically allocate variable spectral width and reach by modifying the device parameters. This is achieved through the support of three types of modulation formats namely PM-QPSK, 8-QAM, and 16-QAM that allow different line rates up to 200Gbps. The parameters of the voyager that can be configured by the voyager agent are the physical interfaces, the modulation formats, the link speed, the power and the Forward Error Correction (FEC). Additionally, it can switch traffic on a configurable wavelength on its transponders and thus acts as a gateway between the packet and optical domains for the network. Voyager has 12 QSFP/QSFP28 Ethernet ports and four DWDM ports that can be configured from the control plane. The Ethernet ports are internally connected to the Broadcom Tomahawk ASIC (BCM56960 SERIES) and they receive the aggregated traffic from the FPGA which is encapsulated to OTN signals at the transponder ports.

### 2.3 Wavelength Selective Switches (WSS)

The Wavelength Selective Switch (WSS) performs filtering and switching of the optical signal<sup>5</sup>. The WSS is used in this

architecture as a programmable 4x16 optical switch that multiplexes and demultiplexes the optical signals to specific ports. As it can be seen in Fig. 1, one WSS is connected to the voyager and another one to the TSON output ports. The WSS' multiplex and demultiplex four wavelengths with different bandwidth from the voyager/TSON ports.

## 3 Control plane

In order to bring flexibility and scalability to this architecture, a control plane is implemented on top of the disaggregated edge node. The control plane is composed of an SDN controller and device agents that allow to program and dynamically configure the different components of the disaggregated edge node. The SDN controller implements three drivers that can program the FPGA(s), the voyager driver to program the voyager, and the WSS driver to program the WSS. In order to optimize the programming time, the SDN controller uses the Multiprocessing Technic to program each component of the disaggregated edge node. The SDN controller receives a REST request containing the description of the network services to be deployed. This request specifies the FPGA ingress and egress ports, VLAN tags, Transport network functions (TSON or Ethernet), TSON parameters, modulation format, FEC, power and central frequency of the voyager BVT. The SDN controller, based on this request, can separate the parameters into different sets and sends them to the appropriate drivers in order to configure the agents. Several agents can be connected to the same driver. Each driver can identify the required nodes and can send the configuration to the appropriate agent via the REST API. In addition, FPGA and WSS agents have been developed. The FPGA agent receives ports information such as VLAN tags, transport network functions, and TSON parameters. Then, it translates the information to an appropriate format and programs the FPGA configuration registers via its Peripheral Component Interconnect Express (PCIe). Voyager receives the configuration parameters from the voyager driver at the SDN controller. These parameters consist of VLAN tags, ports, modulation format, FEC and power. The WSS agent receives the optical parameters including bandwidth and port. Then, it creates an abstraction of the configuration and configures the WSS.

## 4 Testbed Setup and Implementation

We have employed Xilinx vcu108 evaluation boards for the implementation. Each edge node contains two FPGAs. Fig. 3 shows the testbed setup architecture with two disaggregated edge nodes. The edge nodes are connected to 10 x 10Gbps ethernet traffic analysers from one side and from the other side to the Bristol City Metro Network and 100km/200km optical link. The 10Gbps traffic streams can be aggregated to 40Gbps traffic that is sent to either the long-haul network via voyager

and WSS or transferred to the metro network based on different control policies.

## 5 Experimental Results

We have validated the functionality of the edge nodes by applying different control policies on the fly using the SDN controller for both metro and long-haul networks at the same time. Two and three different scenarios are considered for the experimental evaluation of the metro and long-haul networks, respectively. The first scenario involves back-to-back connection of two disaggregated edge nodes for both networks with standard Single Mode Fibre (SSMF).

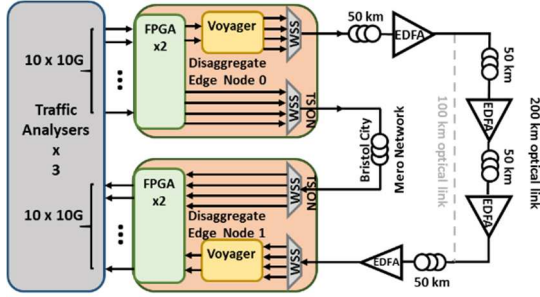


Fig. 3 Disaggregated Edge Nodes testbed setup architecture

In the second scenario for the metro network, the proposed nodes are evaluated over the Bristol City Metro network with 8km of optical fibre. In the second and third scenarios for the long-haul network, the nodes are evaluated over 100 km/200 km of optical fibre. We have evaluated the nodes using a fixed frame of 1500B length. Two different bandwidth granularities have been considered to evaluate the metro network: fine and coarse. In the fine granularity case, the TSON packet size is the same as the ethernet frames i.e. 1500B with 10Gbps bandwidth. In the coarse granularity case, the TSON packet size is 15000B with 50% utilisation. This means that two 5Gbps Ethernet clients are mapped to one TSON wavelength to use the full line rate capacity of 10Gbps and each TSON includes 10 Ethernet frames. The Ethernet performance parameters under consideration include Bit Error Rate (BER) and latency. Latency is defined as the time difference between the arrival of a frame at the analyser, and its departure from the analyser.

Table 1 Bristol City Metro and Long-Haul Networks latency

Destination	Traffic Granularity	Latency (us)
B2B, Metro	Fine	9.5
B2B, Metro	Coarse	32.5
8 km	Fine	48.4
8 km	Coarse	71.2
B2B	-	12.3
100 km	-	503.3
200 km	-	996.2

Table 1 shows the latencies for the mentioned scenarios. The edge nodes latency for the metro network is less than 30% in this case for the fine granularity scenario. For the coarse

granularity, the latency is highly dependent on the TSON frame size and data rate. The long-haul latency is increasing linearly with distance as expected. Fig. 4 (a) shows the BER for the metro network case. A negligible penalty lower than 1dB is observed for 8km transmission compare to B2B scenario.

Fig. 4 (b) displays the BER for the long-haul network scenario, where the worst-case scenario corresponds to the voyager modulation of 16QAM. The increased BER corresponding to the 100km and 200km cases are due to the amplifier noise and the dispersion imposed by the optical fibre transmission.

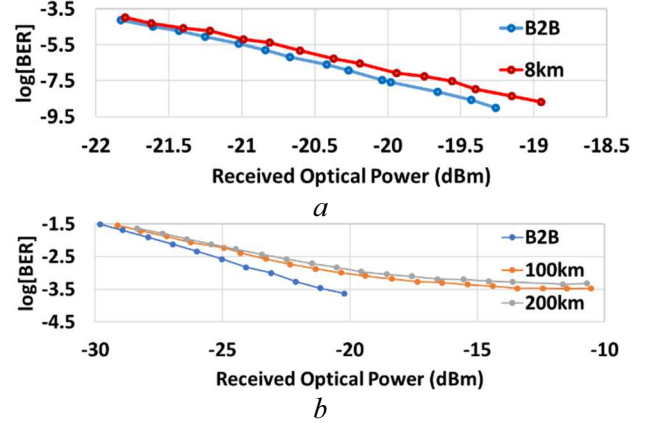


Fig. 4 (a) Metro Network BER, (b) Long-Haul Network BER

## 6 Conclusion

We have proposed a state-of-the-art SDN enabled programmable disaggregated edge node as an outcome of the EU 5G-PPP, Metro-Haul and 5G-PICTURE projects, suitable to support 5G transport network requirements that can extend to both metro and long-haul network reach. An SDN controller and device agents are developed to program and dynamically configure the different components of the disaggregated edge node. The nodes are evaluated over the Bristol City metro network and 100km/200km of transmission fibre. Results showed that low latency and power penalty for both scenarios.

## 7 Acknowledgements

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